# Methyl Bromide *Alternatives*

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## Inside This Issue



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This newsletter provides information on research for methyl bromide alternatives from USDA, universities, and industry.

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## What If...? The Tomato Industry Without Methyl Bromide

The tomato industry is facing the upcoming 50-percent methyl bromide reduction in 2001 with bated breath. Tomato growers, both in California and Florida, produce almost all processing and fresh winter market tomatoes in the United States, and will undoubtedly feel the pain of the methyl bromide ban.

In a "what if" scenario, what would happen to the industry if methyl bromide were suddenly unavailable to tomato growers? A select group of extension agents, growers, and researchers in the tomato industry was presented with this scenario. A synopsis of their responses follows.

Tomato crops have the highest consumption of methyl bromide of all crop uses. Tomato crops account for 23 percent of preplanting methyl bromide use. About 3,700 tons is applied annually to the crop to control diseases, nematodes, insects, and weeds.

Some things became quite evident: California tomato growers are much less dependent on methyl bromide than Florida growers, with less than 5 percent of tomato crops treated with methyl bromide. As a result, the processing-tomato industry in California will be relatively unaffected. Conversely, Florida will bear the brunt of the economic impacts of the reduction in methyl bromide.

### Methyl Bromide Alternatives

In California, Telone has proven a quite efficient fumigant. "Telone is a good nematocide, maybe better than methyl bromide," says Thomas Trout, research leader for the ARS Water Management Research Laboratory in Fresno, California. But there are extensive restrictions attached to Telone applications, including 300-foot setbacks, township limits, and personal protective equipment that must be worn by applicators and field workers. Trout asserts, "Township caps shouldn't be a problem, but the required 300-foot setbacks and protection gear may hurt growers."

According to John Leboeuf, research coordinator for the California Tomato Commission, "the methyl bromide ban is a non-issue for California fresh market tomatoes." Processing-tomato growers in California also use little of the soon-to-be-banned chemical, minimizing negative effects from its absence.

The picture in Florida is decidedly more precarious. Florida growers have used methyl bromide for decades to control nematodes, weeds (including nutsedge), and fungi. Currently, Florida accounts

for about 30 percent of preplanting methyl bromide in the United States, most of which is used on tomato crops. A combination fumigant treatment of Telone C-17 and Tillam seems to provide nearly the same pest control as methyl bromide. Again, local regulations make the use of this combination costly, since Florida must also abide by 300-foot setbacks and personal protection apparel criteria per federal and local regulations.

**The Florida Story**

Each year Florida produces virtually all of the fresh market tomatoes grown in the United States from December to May and about half of all the domestically produced fresh market tomatoes in the country. Less than 1 percent of Florida tomato production is used for processing each year. Some 37,360 acres of tomatoes for the fresh market were harvested in Florida during the 1998-1999 processing year. Over 1.4 billion pounds of Florida tomatoes were shipped, with a total value at the farm level exceeding $419 million.

Several methyl bromide alternatives have been tried by growers with varying levels of success. Telone is effective as a nematocide, chloropicrin is used for disease, and Tillam for weed control. Other species-specific herbicides are used for control of weeds not destroyed by Tillam, according to many growers. But the industry has, out of necessity, reverted to agricultural controls of the past. “We’ve had to go back to technology that is 20 to 30 years old,” says Wesley Roan of Farm-Op Inc., a Florida co-op. “We have to tweak the old technology to make it work as best we can.”

For now, growers can expect some temporary beneficial relief from residual effects of methyl bromide. “Growers will get about two seasons of residual benefits in single crop farms,” according to Joseph W. Noling, an extension nematologist with the University of Florida’s Institute of Food and Agricultural Sciences at Lake Alfred, Florida. However, will the costs outweigh the benefits?

**Economic Effects**

The use of Telone will require additional personal protective equipment that must be worn by applicators and field workers. Using a combination of Telone and Tillam will result in alterations to preharvest costs, ranging from $84 per acre decline for fall tomatoes grown in west central Florida to an increase of $36 per acre for both spring and fall tomatoes grown in southwest Florida, as theorized by John Van Sickle, an agricultural economist with the University of Florida’s Food and Resource Economics Department at Gainesville. In his paper, “Impact of a Methyl Bromide Ban on the U.S. Vegetable Industry,” Van Sickle maintains there is an even greater variation in cost for double-cropping systems where tomatoes are the primary crop. In those cropping systems, cost effects range from a decrease of $61 per acre for a double crop of tomatoes and cucumbers grown in southwest Florida to an increase of $255 per acre for a double crop of tomatoes and squash grown in west central Florida.

Tomato yields in each of these cropping systems are expected to decline 10 percent in all areas except Dade County, where yields are expected to decline by 20 percent due to regulatory restrictions on Telone use. According to the Florida Tomato Committee, the total cost of producing and harvesting tomatoes in Florida averages over $10,500 per acre, with some variation between growing areas.

As a result of these economic pressures, tomato production in Dade and Palm Beach Counties in Florida is expected to effectively end without methyl bromide. Southwest Florida and Mexico are expected to increase production acreage, offsetting most of the loss in Dade and Palm Beach Counties. Total tomato production is expected to decrease about 2.5 percent in all areas because of the lower productivity anticipated in switching to methyl bromide alternatives. While the average wholesale price is expected to increase less than 1 percent, tomato growers can expect a decrease of $15.7 million in total revenues.

Florida is projected to lose $68.8 million in shipping point revenues, with Mexico increasing its shipping point revenues by $51.5 million. As postulated, Florida will lose significant market share and shipping point revenues and Mexico will proportionately gain market share and shipping point revenues.

The pressures on tomato growers in Florida are tremendous, and says Noling, “with the 50 percent reduction, the rubber is going to hit the road in 2001.”

## Weeds, Weeds, Weeds

Weeds. These unwanted plants can often bring a farm to its knees. One of the worst is nutsedge. Of the various types of weed, perennials

such as nutsedge pose a significant problem because of their multiple reproductive systems.

Perennial weeds live for more than 2 years, regrowing each year from roots or rhizomes—tubular extensions below the soil surface—or from seed.

Methyl bromide is fairly effective in managing nutsedge, but alternatives are limited. “Though Tillam and Devrinol provide some nutsedge control, they are not nearly as effective as methyl bromide” says ARS weed scientist Erin Rosskopf of the Horticultural Research Laboratory in Fort Pierce, Florida. “Integrated weed management is necessary.”

One part of integrated weed management that is under consideration is biological control—using living organisms to control pest organisms. Rosskopf’s lab, in a cooperative project with R. Charudattan at the University of Florida, is evaluating a fungus as a biological control for purple and yellow nutsedge. The isolate was highly pathogenic to purple and yellow nutsedge, as well as globe sedge and rice flatsedge.

In the lab, purple nutsedge was inoculated with *Dactylaria higginsii* conidial suspensions, which resulted in significant reductions in shoot numbers, shoot dry weight, and tuber dry weight. The fungus was also tested in the field against purple nutsedge. Three postemergence applications resulted in about a 90 percent mortality of purple nutsedge. Greenhouse studies of purple nutsedge in tomatoes showed that *D. higginsii* reduced nutsedge competition so that tomato yields were equal to those from the weed-free control. Laboratory and field trials are currently being conducted to determine the compatibility of *D. higginsii* with postemergence pesticide applications.

The loss of methyl bromide to control nutsedge poses particular problems for minor crops such as tomatoes, peppers, and strawberries, since there are few chemical herbicides registered for use. Even with methyl bromide, losses in fresh market tomatoes in Florida due to weed pressure have been estimated at more than $291 million. Without methyl bromide that figure could substantially increase.

But nutsedge is an equal opportunity pest, striking agricultural crops the world over. Though nutsedge has earned a reputation as the world’s worst weed, it is by no means the only one.

**Types of Weeds**

Weeds fall into three types: annuals, biennials, and perennials. Annual weeds are plants that reproduce by seed and germinate each year. Some common annual weeds include foxtail, velvetleaf, and cocklebur.

Winter annuals germinate in the fall and complete their reproductive cycle in the spring or early summer. This type of weed is likely to be found in winter-sown grains, no-till crops, or pastures where the soil remains undisturbed during the winter months. Summer annuals germinate in the spring and seed out in late summer or fall. Summer annuals flourish when summer annual crops such as corn or soybeans are grown, competing directly with the crop for resources.

Biennial weeds live through two growing seasons, although they also reproduce via seed. The first year is devoted to vegetative growth, and the second year has both vegetative and reproductive growth. Because of the 2-year cycle of growth, these weeds are found in areas of low soil disturbance such as pastures, waterways, and fence rows.

Perennial weeds grow for more than two years and are quite versatile, able to thrive in both areas of reduced soil disturbance or fields of row crops.

Plant seeds are dispersed in a variety of ways. Leafy spurge seed pods build up pressure and explode, shooting seeds up to 15 feet away. Small mammals and birds eat some seeds, carrying them away from the parent plant. Some seeds, like those of the dandelion, can become airborne and float away. Other seeds can attach to the fur of animals, thus hitching a ride to new locations.

**Weed Management**

“Weeds have a huge impact in yield and increased labor costs in agriculture,” says Rosskopf. But in order to control them, weeds must first be correctly identified. Field scouting allows for identification and recording of all weed species found. Severity of infestation also needs to be determined by noting the number of weeds per row and their height relative to crops.

There are various methods of weed control: mechanical, chemical, crop rotation, and biological control. Some other less-utilized methods include controlled burning and crop competition.

Mechanical control can involve several different methods. Burial, by which all growing plants are buried under the soil surface, is most effective on annual weeds. It is less effective on perennial weeds, which have underground root systems and are capable of regrowth. Another method of mechanical control is cultivation—cutting the root systems of weeds. However, care should be taken because deep cultivation can damage crop roots. Deep cultivation may also pull more weed seeds to the soil surface where they will germinate.

Crop rotation is yet another method. If the same crop is planted in the same field year after year, weeds will appear that have become tolerant of the cultural practices and herbicides used on the crop. By rotating to other crops, the types of cultural practices and herbicides will change, thus not allowing weeds to become adapted to any particular regimen.

Chemical control is flexible in that it can be administered preplanting, pre-emergence and postemergence. Application can be broadcast, band, directed, or spot treatment, depending on weed type, severity of infestation, and location.

Biological control has not been used as a weed control agent to a great degree, but that may be changing. While no side-by-side herbicide tests have been conducted yet, *D. higginsii* seems to provide excellent control of nutsedge by acting as a foliar plant pathogen. Rosskopf maintains, "since there aren't any herbicides that are close to methyl bromide in effectiveness against weeds, biological controls may fill the niche." A potential advantage to its use in existing production systems is that it can be applied like any other foliar herbicide.

"Sometimes, it is forgotten that weeds have such a big impact on production systems. But it is still an area we need to continue to address," says Rosskopf. Weeds have been around for millennia, but methods exist to control them—albeit not without a fight.

## Sulfuryl Fluoride: The Postharvest Fumigant of the Future?

Sulfuryl fluoride is considered by many to be the postharvest fumigant of the future, replacing the soon-to-be-eliminated methyl bromide. Under the trade name Vikane gas fumigant, it is currently registered for structural fumigations to combat wood termites and wood-boring beetles. Dow AgroSciences has begun EPA registration procedures to allow its use in postharvest situations.

Unlike methyl bromide, which is being phased out because it was determined to be an ozone depleting substance, sulfuryl fluoride is not an ozone depleter.

Dow AgroSciences is pursuing the registration of sulfuryl fluoride as a gas fumigant for postharvest use in dry fruits, tree nuts, and cereal grains. The postharvest formulation of sulfuryl fluoride will be called ProFume gas fumigant. Tolerance testing is currently under way on each of the food types, with the ultimate goal of phasing in the use of ProFume as methyl bromide is being phased out. According to Brian Schneider, Dow AgroSciences' ProFume biology development leader, this should be an accomplishable goal. "We have a jump-start since sulfuryl fluoride is already registered for structural uses," contends Schneider.

In structural fumigation, methyl bromide and sulfuryl fluoride are applied in a similar manner, and confinement procedures must be strictly adhered to for both. Schneider says sulfuryl fluoride penetrates organic substrates better than methyl bromide. "Because sulfuryl fluoride is an inorganic material, as opposed to the organic methyl bromide, it doesn't bind onto items being protected, so more of the chemical is available to get to the insects," says Schneider.

Sulfuryl fluoride is very effective against the active life stages of postharvest insects, according to ARS entomologist J. Larry Zettler of the Horticultural Crops Research Laboratory in Fresno, California. But sulfuryl fluoride requires more fumigant for egg stages than for other postembryonic stages. "But increasing exposure time or temperature may increase the chemical's effectiveness on eggs," comments Zettler.

In studies Zettler conducted with colleague Richard F. Gill, lab-reared codling moths and navel orangeworms were exposed to vacuum-chamber fumigation of a little more than an ounce of sulfuryl fluoride per cubic meter of air. The dose and length of exposure resulted in total insect kill. Codling moths and navel orangeworms are established pests of walnuts. "It has great potential as a tool in postharvest fumigation," says Zettler.

The dried fruit and nuts industry is excited about the results so far. Mike Hurley, laboratory director of the Dried Fruit and Tree Nut Association of California, feels sulfuryl fluoride will prove helpful. "Though not as effective as methyl bromide, sulfuryl fluoride is in the lead as an alternative."

Toxicity is an ever-present issue that Dow AgroSciences will address in EPA-mandated toxicity tests. According to Hurley, "sulfuryl fluoride leaves no parent compound residue on foods," meaning less chemical exposure to consumers. Fluoride residues in food commodities may be increased, however, with levels dependent on the type of commodity and fumigant dosage.

Toxicity is only one feature of sulfuryl fluoride that Dow AgroSciences is committed to understanding. Dow AgroSciences is looking at ways to achieve optimal fumigation efficiency employing more efficient gas introduction procedures, improved sealing techniques, use of heat to increase susceptibility, and gas monitoring during exposure. They are also working with industry, university, and ARS researchers to help understand insect pest infestation action levels and economic thresholds to provide guidance to fumigators on treatment timing and the most economical dosages.

Pest population rebound is a significant issue for all postharvest fumigants. Several variables are involved in population rebound including gas concentration in the building, immigration, and temperature. Dow AgroSciences is looking at ways to bring about peak fumigation efficiency. Maintaining adequate gas concentration throughout the building to produce insect kill is crucial in that equation. Currently, Dow AgroSciences is also conducting modeling studies of insect population rebound after fumigation in mills and processing plants. This work complements similar research being conducted by Jim Campbell at ARS, Manhattan, Kansas, in feed mills fumigated with methyl bromide.

Though sulfuryl fluoride must undergo rigorous EPA registration procedures, its approval will provide an acceptable alternative to methyl bromide, thus filling a substantial need for postharvest fumigants.

## Fumigant Receives EPA Registration

Cytec Industries issued a press release to announce that Eco2Fume fumigant gas received full food registration from the U.S. Environmental Protection Agency on August 29, 2000. This will allow the fumigant, a premixed cylinderized phosphine and carbon dioxide mixture, to be used by trained and certified applicators for food items. The fumigant gas is expected to replace methyl bromide in flour mills and grain and food processing plants where possible. Eco2Fume is the first methyl bromide alternative to receive full EPA registration.

Cytec Industries instituted a stewardship program and named Fumigation Service and Supply as the coordinator for Eco2Fume users. The stewardship program will train fumigators to use this new phosphine-generating delivery system in commodities and structures. For more information about Eco2Fume and the stewardship program, contact David Mueller at (317) 896-9300.

## Technical Report

### Soil Fumigant and Herbicide Combinations for Soilborne Pest Control in Caladium

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Greater than 95 percent of the world's production of caladium tubers occurs in a small geographical area near Lake Placid, Florida. Most of the production is on muck or high organic matter soils. Soilborne pest control is a major problem for caladium producers with pests ranging from weeds to root-knot nematodes and soilborne diseases, such as *Fusarium*. Although most caladium growers fumigate their soil with methyl bromide, results of research over the years have not demonstrated a clear response to soil fumigation under all conditions. Growers routinely soak their tubers in hot water as a means of killing root-knot nematodes and some superficial disease inoculum, but it has only been where root-knot nematode populations in the soil were high that a response to soil fumigation was demonstrated in previous research in muck soil. Few caladiums are produced in mineral soils (fine sand) in Florida, but for those which are grown in these soils, a very positive response to soil fumigation has been demonstrated. In none of this early research was there an effect on soilborne disease control in the tubers at harvest as a result of fumigation, especially

with regard to *Fusarium* sp. which infected all of the tubers in the few previous studies, whether grown in fumigated or nonfumigated soil, suggesting that the source of this disease was the planting stock itself. Various fumigants have been evaluated over the years, including mixtures of dichloropropene, dichloropropane and methyl isothiocyanate (Vorlex), 1,3-dichloropropene + 1,2-dichloropropane (D-D), and 1,3-dichloropropene + chloropicrin (Telone C-17 or C-35), as well as metam, but none are believed to be as effective as methyl bromide/ chloropicrin mixtures for control of all the pest spectrum.

Although methyl bromide is generally thought to be very effective against most weed propagules, weeds often are a problem in caladiums due to the long growing season (8 to 9 months). For many years growers relied upon alachlor for weed control, but it was withdrawn from sale in Florida in the mid 1980's, leaving growers with no reliable substitute. Research during the 1980's demonstrated that oryzalin could be used successfully for weed control in caladium in both mineral and organic soils and later metolachlor also was demonstrated to be an effective herbicide for use in caladiums. As a result, growers have developed weed control programs using these herbicides and selective hand weeding, but the programs almost always are used in combination with methyl bromide due to the multiple pest complex generally encountered during tuber production.

Historically, growers have relied upon soil fumigation with methyl bromide to control soilborne pests; however, the impending phaseout of methyl bromide will eliminate that practice. To find a suitable alternative to methyl bromide as a soil fumigant in caladium tuber production, a two-year study was initiated on a commercial farm near Lake Placid, FL, beginning with the 1998 crop season, to assess the efficacy of selected soilborne pest control programs consisting of combinations of soil fumigants and herbicides.

The test area was located on a sandy muck soil south of Lake Placid, FL, and, like most commercial tuber farms in the area, the test area had been fumigated with methyl bromide for several years prior to test initiation. Treatments were applied to 50 ft long by 22 ft wide plots which were arranged in a randomized complete block design and replicated 6 times. Each plot contained 5 beds, consisting of 4 rows each. Fumigant treatments evaluated each of the two years consisted of 1) no fumigant; 2) methyl bromide/chloropicrin (90/ 10 percent) at 450 lbs./acre; 3) 1,3-dichloropropene (1,3-D)/chloropicrin (83/17 percent) (Telone C-17) at 35 gal./acre; and 4) 75 gal. of metam sodium (Vapam) per acre + 200 lbs. of chloropicrin (pic) per acre. Metolachlor herbicide (8 lbs./acre) was applied at planting to plots treated with 1,3-D or metam, in 1998. Oryzalin (4 lb./acre) was applied at planting during 1999. All fumigant treated plots, including the methyl bromide plots, received an over the top application of oryzalin (4 lb./acre) 7 weeks after planting in both 1998 and 1999. The nontreated control received no fumigant or herbicide during the course of this experiment.

Data collected at appropriate intervals included crop plant vigor, weed control by species, numbers of nematodes in the soil, plant disease observations and tuber production. Weed control was evaluated five times during the season and all plots were hand-weeded after each evaluation. The predominant weed species present were *Digitaria ciliaris* (Retz.) Koel. (crabgrass), *Amaranthus viridis* L. (pigweed) and *Portulaca oleracea* L. (purslane). Caladium tubers were dug from the center bed of each plot in January and February of the following year with a commercial digger, collected into crates, and transported to a caladium barn where they were washed free of soil and debris and stored in ventilated crates to dry. Approximately two weeks later all tubers were sorted and hand graded into the industry-standard commercial size grades. A production index assessment which provides a numerical scale to relate tuber production to the number of number one size tubers also was determined.

Plant vigor in 1998 was higher in methyl bromide treated plots in midsummer, but by mid-fall plants in areas treated with 1,3-D + chloropicrin were just as vigorous as those where methyl bromide had been applied. During 1999, caladiums grown in 1,3-D + chloropicrin treated soil appeared to be the most vigorous, but were no more vigorous than those grown in methyl bromide fumigated soil. Early control of weeds was good with those treatments which received herbicide at time of planting (metolachlor in 1998 and oryzalin in 1999), but methyl bromide allowed an early infestation of crabgrass and pigweed, indicating that it would have benefitted from herbicide application at planting and suggesting that loss of methyl bromide from the upper 2 inches of the soil may have been too rapid for good weed

control in this test. Subsequent evaluations of weed control indicated that application of herbicide (metolachlor or oryzalin) at planting followed by an over-the-top application of oryzalin approximately 7 weeks later, all combined with occasional hand weeding, provided acceptable weed control until late fall when caladium growth was slowing and growers generally are not concerned with weed control. The choice of soil fumigant had little to no effect on weed control when combined with herbicide. The impact of an effective herbicide program was seen in the total number of weeds counted in the plots over the season as there were 10 to 20 times as many weeds present where herbicide was not applied than where it was used, in spite of multiple hand weedings. By the time of harvest in January and February, 72 percent of the soil surface was covered with weed growth in the nontreated plots whereas only about 20 percent of the soil surface was covered in plots which received herbicides as well as fumigants.

Nematodes were not a factor in this study. Even though each treatment plot was located in the same spot each of the two years, few nematodes were found in soil or tissue samples. *Fusarium* was detected in tubers prior to planting at an incidence of 100 percent in 1998 and slightly less in 1999, whereas *Pythium* was not detected. There were no significant differences among treatments for incidence of any disease organism in either year of the study. When the tubers were inspected and sampled for disease organisms after harvest, *Erwinia, Fusarium, Pythium* and *Rhizoctonia* were found in most of the tubers. Soil fumigation had no effect on incidence of these organisms in the tubers at harvest.

Tuber production was determined for each treatment after digging, washing and drying the tubers in January 1999 and February 2000. There was no difference in production for any size grade, except jumbo, where significantly more tubers were produced in plots treated with 1,3-D + chloropicrin with metolachlor at planting followed by oryzalin in mid summer in 1999. There were no differences in jumbo production between methyl bromide or metham + chloropicrin or where no fumigant or herbicide was applied in the first year of this study. During the second year of the study, there were no differences in production of any size grade of caladium tuber with the fumigant/herbicide combinations. Yield was as good with no fumigant or herbicide applied as it was where fumigant and herbicide were used. Cost of production was different because labor for hand weeding was a major expense for the nontreated control plots. Thus, although there was not a direct effect on tuber yield of the fumigant/herbicide option chosen, there was an indirect effect on the economics of production.

Previous use of methyl bromide on this field may have influenced results by reducing pest levels below what might have been observed in an area which had not been subjected to repeated applications of methyl bromide. Many scientists expect this effect to exist and carry forward for several years into the future once methyl bromide use ceases. Caladium growers have reported that they can count on only one year of grace past the season in which they use methyl bromide. In the past when they have used other fumigants in subsequent years, the first year of an alternative has been successful, but if they try for a second year they usually suffer reduced yields and poorer soilborne pest control. Lack of more significant differences in pest levels and tuber production in this study suggest 1) the levels of soilborne pests were moderate to low in this field at the time of fumigant application, 2) tubers already contained some pests and this masked treatment differences, or 3) soil fumigation or the fumigants tested are not useful under the current production system. Caladium tubers were hot water treated prior to planting to kill root-knot nematodes within the tissue, thus nematodes would be observed only if they were present in the soil. Since nematodes were not recovered from soil samples during the season or tubers at the time of harvest, it is apparent that nematodes were not present in the test area. We observed a slight response to soil fumigation in the form of an increase in production of jumbo size tubers with 1,3-D + chloropicrin and herbicide during 1998 but none in 1999. Previous research, as well as the current study, demonstrate that planting tubers already infected with *Fusarium* prior to planting guarantees *Fusarium* as a pest in caladiums, regardless of soil fumigation.

Results of this research suggest that 1,3-D + chloropicrin (83/17 percent, Telone C-17) at 35 gal/acre may be a viable replacement for methyl bromide when combined with metolachlor or oryzalin herbicide at planting followed by a midsummer application of oryzalin. Furthermore, it was observed that even methyl bromide would have benefitted from application of herbicide at planting to control early weed emergence

and growth, especially that of crabgrass and pigweed. This work is being continued in an effort to determine the long term effects of these fumigant/herbicide combinations on pest control and tuber production.